UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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COLUMBIA RIVER

TEMPERATURE ASSESSMENT:

TEMPERATURE MODEL

PROGRESS REPORT

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PROGRESS REPORT

- **EXPAND FINITE DIFFERENCE GRID TO IMPROVE ACCURACY AND REDUCE NUMERICAL DISPERSION.**
- **REFINE NUMERICAL SCHEME TO IMPROVE HIGH FREQUENCY RESPONSE.**
- **INCORPORATE ERROR PROPAGATION ALGORITHM INTO TEMPERATURE PREDICTION SOFTWARE.**
- **BEGIN PARAMETER ESTIMATION FOR ERROR PROPAGATION MODEL USING USGS TEMPERATURE DATA.**
- **DEVELOP CONCEPTUAL MODEL FOR HYPOTHESIS TESTING.**

EXPAND FINITE DIFFERENCE GRID

- **INCREASE NUMBER OF SEGMENTS IN MAIN STEM COLUMBIA RIVER FROM 39 TO 146 FOR SCENARIOS WHICH INCLUDE DAMS. NO CHANGE IN NUMBER OF SEGMENTS FOR SCENARIOS WITHOUT DAMS.**

- **INCREASE NUMBER OF SEGMENTS IN MAIN STEM SNAKE RIVER FROM 16 TO 139 FOR SCENARIOS WHICH INCLUDE DAMS. NO CHANGE IN NUMBER OF SEGMENTS FOR SCENARIOS WITHOUT DAMS**

- **ADD TUCANNON RIVER AND PALOUSE RIVER INPUT.**

REFINE NUMERICAL SCHEME

- **NUMERICAL SCHEME IS A HYBRID EULERIAN-LAGRANGIAN METHOD**

- **LAGRANGIAN STEP USES REVERSE PARTICLE TRACKING**

- **EULERIAN STEP USES THIRD-ORDER POLYNOMIAL FIT**

ERROR PROPAGATION ALGORITHM

System Model: $\underline{x}_k = \phi_{k-1}\,\underline{x}_{k-1} + \underline{w}_{k-1}$ $\quad \underline{w}_k \sim N(\underline{0}, Q_k)$

Measurement Model: $\underline{z}_k = H_k\,\underline{x}_k + \underline{v}_{k-1}$ $\quad \underline{V}_k \sim N(\underline{0}, R_k)$

State Estimate Extrapolation: $\underline{x}_k(-) = \phi_{k-1}\,\underline{x}_{k-1}(+)$

Error Covariance Extrapolation: $P_k(-) = \phi_{k-1}\,P_{k-1}(+)\phi_{k-1} + Q_{k-1}$

State Estimate Update: $\underline{x}_k(+) = \underline{x}_k(-) + K_k[\underline{z}_k - H_k\,\underline{x}_k(-)]$

Error Covariance Update: $P_k(+) = [I - K_k\,H_k]\,P_k(-)$

Kalman Gain Matrix: $K_k = P_k(-)H_k^T[H_k\,P_k(-)H_k^T + R_k]^{-1}$

Potential Applications:

- **Real time state and error covariance estimates improved by combining system and measurement models**
- **Predicted state and error covariance estimates with system model**
- **Improve sampling strategies**
- **Develop hypothesis**

PARAMETER ESTIMATION

- **WATER TEMPERATURE DATA BASE DEVELOPED BY USGS USED TO ESTIMATE SYSTEM MODEL AND MEASUREMENT ERROR**

- **PARAMETER ESTIMATION IS IN PROGRESS**

HYPOTHESIS TESTING

18. SEQUENTIAL TESTING USING LIKELIHOOD RATIO

    a. BINARY TEST WITH NULL HYPOTHESIS AND ALTERNATIVE HYPOTHESIS

    b. LIKELIHOOD RATIO GENERATED BY KALMAN FILTER

    c. DETERMINE NUMBER OF SAMPLES REQUIRED TO DETECT THE DIFFERENCE BETWEEN TWO DIFFERENT TREATMENTS

19. PROBABILITY THAT EXCEEDANCE OF SOME CRITERION IS DUE TO TREATMENT

    a. BINARY TEST WITH TWO TREATMENTS

    b. PROBABILITY DISTRIBUTION FOR EACH TREATMENT GENERATED BY KALMAN FILTER

    c. ESTIMATE PROBABILITY THAT EXCEEDANCE OF CRITERION IS DUE TO TREATMENT #1 AND COMPARE TO PROBABILITY THAT EXCEEDANCE IS DUE TO TREATMENT #2

PROPOSED TESTS

1. TREATMENT #1 IS DEFINED AS THE HYDRAULIC CONDITIONS IN THE COLUMBIA AND SNAKE RIVERS GIVEN THERE ARE NO DAMS. TREATMENT #2 IS DEFINED AS THE HYDRAULIC CONDITIONS IN THE COLUMBIA AND SNAKE RIVERS GIVEN THE EXISTING DAMS. THE HYDROLOGY AND METEOROLOGY ARE ASSUMED TO BE THE SAME FOR BOTH AND ARE DESCRIBED BY THE EXISTING LONG TERM RECORD.

2. TREATMENT #1 IS DEFINED AS THE HYDRAULIC CONDITIONS IN THE COLUMBIA AND SNAKE RIVERS GIVEN THE EXISTING DAMS AND TRIBUTARY TEMPERATURES ARE AS ESTIMATED FROM THE EXISTING RECENT RECORD. TREATMENT #2 IS DEFINED AS THE HYDRAULIC CONDITIONS IN THE COLUMBIA AND SNAKE RIVERS GIVEN THE EXISTING DAMS AND TRIBUTARY TEMPERATURES ARE AS ESTIMATED FROM THE EXISTING RECENT RECORD, EXCEPT THE TEMPERATURES WILL NOT BE ALLOWED TO EXCEED THE APPLICABLE WATER QUALITY CRITERIA. THE HYDROLOGY AND METEOROLOGY ARE ASSUMED TO BE THE SAME FOR BOTH AND ARE DESCRIBED BY THE EXISTING LONG TERM RECORD.

3. TREATMENT #1 IS THE YEAR OF RECORD (METEOROLOGIC) WITH THE HIGHEST SEVEN-DAY AVERAGED AIR TEMPERATURES. TREATMENT #2 IS THE YEAR OF RECORD (METEOROLOGIC) WITH THE LOWEST SEVEN-DAY AVERAGED AIR TEMPERATURES. THE HYDROLOGY AND INPUT TEMPERATURES ARE ASSUMED TO BE THE SAME FOR BOTH AND ARE DESCRIBED BY THE EXISTING LONG TERM RECORD.

4. TREATMENT #1 IS THE YEAR OF RECORD (HYDROLOGIC) WITH THE HIGHEST SEVEN-DAY AVERAGED FLOWS. TREATMENT #2 IS THE YEAR OF RECORD (HYDROLOGIC) WITH THE LOWEST SEVEN-DAY AVERAGED FLOWS. THE METEOROLOGY AND INPUT TEMPERATURES ARE ASSUMED TO BE THE SAME FOR BOTH AND ARE DESCRIBED BY THE EXISTING LONG TERM RECORD.

GOALS OF HYPOTHESIS TESTING

1. ASSESS THE IMPACT OF DAMS ON WATER TEMPERATURES IN THE COLUMBIA AND SNAKE RIVERS

2. ASSESS THE IMPACT OF TRIBUTARY INFLOWS ON WATER TEMPERATURES IN THE COLUMBIA AND SNAKE RIVERS

3. ASSESS THE IMPACT OF METEOROLOGY ON WATER TEMPERATURES IN THE COLUMBIA AND SNAKE RIVERS

4. ASSESS THE IMPACT OF HYDROLOGY ON WATER TEMPERATURES IN THE COLUMBIA AND SNAKE RIVERS